Measuring the Thermal-Hydrological Processes in the Drift Scale Test

Yvonne Tsang, Barry Freifeld and Sumit Mukhopadhyay
Contact: Yvonne Tsang, 510/486-7047, ytsang@lbl.gov

RESEARCH OBJECTIVES

Lawrence Berkeley National Laboratory, as part of a multi-laboratory team, is carrying out a large-scale in-situ thermal test, the Drift Scale Test (DST), in an underground facility at Yucca Mountain, Nevada, the potential site for a high-level nuclear waste repository. The heating phase of the DST began in December 1997 and is designed to continue for four years, followed by another four years of cooling. The objective of this test is to gain a more in-depth understanding of the coupled thermal-hydrological-mechanical-chemical processes likely to exist in the fractured rock mass around a geological repository situated above the water table.

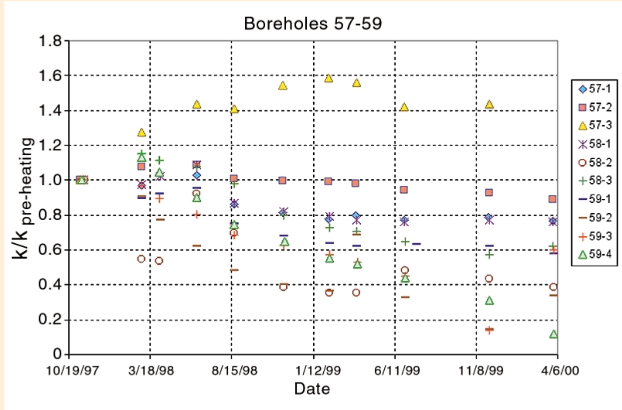

Figure 1. Permeability (normalized to respective pre-heat values) from air-injection into different borehole sections in the DST, at different stages of heating.

APPROACH

The host rock for the DST is densely fractured welded tuff. Permeability in the fractures is orders of magnitude larger than that in the matrix, where pores are about 90% saturated with water. Heat is provided by canister heaters placed in a drift 47.5 meters in length and 5 meters in diameter, and by 11-meter-long rod heaters installed in boreholes drilled perpendicular to the drift axis, pointing to the north and to the south of the heated drift. Approximately 185 kW is supplied by nine canister heaters and 50 rod heaters. The thermally driven hydrological, chemical and mechanical coupled processes are monitored continuously by thousands of sensors installed in nearly 100 boreholes that encompass a rock block of 60 x 60 x 60 m^3. Active testing such as cross-hole radar tomography, neutron logging, electrical resistivity tomography and air-permeability measurements are also performed at quarterly intervals to measure moisture redistribution with time. Moisture redistribution arises chiefly from boiling of water near the heat sources, transport of vapor away from the heat source, and its subsequent condensation in cooler rocks. Thermal-hydrological processes in the DST have been simulated using a numerical model that incorporates realistically the 3-D test configuration. The model predictions are compared to the extensive set of measured data.

ACCOMPLISHMENTS

The main manifestation of coupled thermal-hydrological processes is in the time evolution of the drying and condensation zones. Good agreement occurred between the model predictions and measurements. Specifically, as heating progresses, expanding zones of reduced liquid saturation in the rock matrix around the heaters predicted by the simulations are consistent with zones of drying shown in neutron logging data, cross-hole radar tomograms and electrical resistivity tomography data. Similarly, periodic air permeability measurements show that in those condensation zones where numerical simulations show enhanced liquid saturation in the fractures, the measured fracture permeability to air decreases. Figure 1 shows the measured air-permeability in different borehole sections as a function of time. The air-permeability is normalized to the respective pre-heat values in different borehole sections.

SIGNIFICANCE OF FINDINGS

A close integration of measurements and simulations carried out in this large-scale and long-term test has contributed much toward the understanding of thermally driven coupled processes in a fractured rock in the unsaturated zone.

RELATED PUBLICATIONS

Birkholzer, J.T., and Y.W. Tsang, Modeling the thermal-hydrological processes in a large-scale underground heater test in partially saturated fractured tuff, Water Resour. Res 36(6), 1431-1448, 2000.

ACKNOWLEDGEMENTS

This work was supported by the Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, through Memorandum Purchase Order EA9013MC5X between TRW Environmental Safety Systems, Inc., and Ernest Orlando Lawrence Berkeley National Laboratory for the Yucca Mountain Site Characterization Project under Contract No. DE-AC03-76SF00098.